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RISK ASSESSMENT WITH A PERSONAL COMPUTER

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Abstract

Each year, the Lawrence Livermore National Laboratory (LLNL) reviews all facility and utility upgrade projects to determine their relative ranking in terms of safety benefit versus cost. The process begins when a team of health and safety professionals screens these proposed projects. Using a variation of William Fine's Naval Ordnance Laboratory (NOL) risk scoring system, a microcomputer is used to record, display, and print risk data about each competing project. This information, including a cost-benefit graph, assists line management to reach decisions concerning the relative merit of each project. The spread sheet formatting to perform the risk scoring and cost-benefit analysis is included with this paper.

The Risk Assessment Process at LLNL

This process begins with a small committee of experts who review each proposed facility and utility upgrade project for its safety, health, and environmental merit. The current committee consists of a fire protection engineer, a health physicist, an industrial hygienist, an industrial safety engineer, an environmental engineer, and a safety analyst (J. L. Morse) as Chairman.

The review commences with each member of the committee becoming familiar with each proposed upgrade. This is accomplished by reviewing the detailed proposals with their accompanying justification information. These proposals originate from the program or department managers owning the facility to be improved. Each member of the committee is encouraged to investigate further the merits of each project with the operational managers and safety people involved with each facility.

When the information gathering phase is complete, the committee meets to perform the risk scoring activity described below. An advantage of multiple inputs into the scoring system is that extreme views or biases tend to be dampened. Generally, however, there is reasonable agreement on the risk scores achieved by committee.

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To conduct this risk analysis, any microcomputer (PC) with a spread sheet program can be used. At LLNL, we use an IBM PC running Lotus 1-2-3 software. The advantage of a spread sheet with integrated graphics capability is to show graphically the interrelationships between consequence and probability factors in the risk concept. Also, the ease of entering and manipulating data on the spread sheet format makes sensitivity analysis especially easy. That is, various consequences and probability factors can be changed to instantly see the impact on the risk score and the graphical cost benefit information displayed on the PC. (See Tables 1-5.)

Following the risk scoring activity, the data is printed out and attached to a letter of transmittal to the Laboratory Associate Director responsible for compiling the upgrade package for final Laboratory and DOE approvals.

The Risk Score Analysis

The risk scoring analysis used by LLNL is a variation of a system developed in the early 1970's by William T. Fine, then of the Naval Ordnance Laboratory (NOL). His risk scoring formulas were:

$$\text{Risk Score} = \text{Consequences} \times \text{Exposure} \times \text{Probability} \qquad (1)$$

$$\text{Justification} = \frac{\text{Risk Score}}{\text{Cost Factor} \times \text{Degree of Correction}} \qquad (2)$$

The Laboratory has modified the numerical values given for each factor in the risk formula to fit its needs; but the basic formula and methodology are still used.

Let us review the first formula (1) and its concepts. A consequence is the undesired results of a sequence of events starting with the initiating event. Consequences include: many fatalities, several fatalities, one fatality, serious injuries/illness, minor injury/illness, dollar loss, work delays, and adverse public reaction. There is more than one consequence for a particular hazard, each at a different probability level. However, as the seriousness of a consequence goes up, its probability of occurrence generally goes down. It is important to select the consequence that will result in combination with its probability factor in the greatest risk score.

For ease of calculation, the probability factor is divided into two subfactors.

- Probability that the initiating event will occur (called "exposure" in the NOL system).
- Probability that the consequences specified will occur given that the initiating event occurs (called "probability" in the NOL system).

The probability factors are given in whole numbers (contrary to actual probabilities which are fractions). Although there may be more than two factors identified in making up the total probability, it is usually simplest to break down the total probability into the above mentioned subfactors.

The first probability factor, exposure, deserves a little more explanation. The probability of the initiating event occurring is often related to the "exposure" or the number of times in a given period that the hazard presents itself. For example, a busy intersection has a greater probability of an accident that a seldom traveled intersection, provided that the "hazard" of each is the same. For this reason, one of the ways to estimate the probability of the initiating event is to look at the "exposure" or amount of time the threat is present.

The Risk Score is calculated using the values selected from the tables that follow and inserting them into equation (1) above.

Table 1
CONSEQUENCE FACTORS

Use the following to estimate the value of the consequence:

Description	Score
• Catastrophe • Numerous Fatalities • Extensive Damage (> $25 million) • Major Disruption of Work • Off-Site Health Affected	100
• Several Fatalities • Property Damage ($1-25 million) • Serious Programmatic Interruption	50
• Fatality, Serious Illness (e.g., cancer) • Property Loss ($500,000 to $1 million) • Work Interruption	25
• Permanent Disability, Chronic Irreversible Disease (amputation, loss of eye, etc.) • Property Damage ($100,000 to $500,000) • No Significant Off-Site Threat, But Public Involved With Adverse Publicity	15
• Serious Injuries, Illness (without permanent disability) • Property Damage ($10,000 to $100,000) • No Significant Off-Site Threat, Public Not Involved	5
• Minor Injuries, Illness (i.e., no disability) • Property Loss (< $10,000) • No Work Affect	1

Table 2
PROBABILITY FACTOR FOR INITIATION

Use the following to establish the probability factor for the occurrence of the initiating event. This is referred to as "exposure".

Description	Score
• Continuous Threat • Very Likely to Occur • 95% Probability	10
• Frequent Threat • 50% Probability	6
• Occasional Threat • 1% Probability	3
• Unusual Threat • 0.001 Probability	2
• Rare Threat • 0.00001 Probability	1
• Very Rare Threat, Only Remotely Possible • 10^{-7} Probability or Smaller	0.5

Table 3
PROBABILITY FACTOR FOR COMPLETION *

Use the following to establish the probability factor of the initiating event resulting in the consequences specified:

Description	Score
• Most likely and expected result • 95% Probability	10
• Quite Possible, Not Unusual • 50% Probability	6
• Unusual Sequence of Coincidence • 1% Probability	3
• Remotely Possible Coincidence • 0.001 Probability	2
• Extremely Remote Possibility • 0.00001 Probability	1
• Practically Impossible • 10^{-7} Probability or Smaller	0.5

*equivalent to Likelihood in Fig. 2.

The Justification Analysis

Once a project has been identified to treat a safety, health, or environmental problem, appropriate corrective action must be tentatively decided upon and its costs estimated. Using the risk score discussed above, we can now use two operative elements, the cost and the degree of correction, to determine an index of justification.

$$\text{Justification} = \frac{\text{Risk Score}}{\text{Cost X Degree of Correction}} \tag{3}$$

or

$$J = \frac{RS}{C \times DC} \tag{4}$$

The cost (C) is the estimated dollar cost of the proposed corrective action. The dollar unit is dropped to create a "pure" number for comparison.

The degree of correction (DC) is an estimate of the degree to which the proposed corrective action will reduce the identification risk. (A safety improvement project may attempt the containment of a consequence, the elimination or mitigation of a hazard, the interruption of an accident sequence, or a combination of these approaches.) Degree of correction values are as follows:

Identified Risk	Score
• 100% eliminated.	1
• Reduced to at least 75%.	2
• Reduced by 50% to 75%.	3
• Reduced by 25% to 50%.	4
• Reduced by less than 25%	6

Values are substituted into the formula to determine the numerical value for justification. Projects can then be ranked by justification for management action. Notice that if cost (C) is removed from the justification formula, then another useful value, benefit (B), can be defined. Cost (C) and benefit (B) may be plotted on the "x" and "y" axes to give a smooth curve showing benefit versus cost (see Fig. 1). In Figure 1, notice that the more deserving projects tend to fall on the left side of the curve where great benefit is derived from modest cost. The use of cumulative cost on the "x" axis allows the manager to conveniently see his budget limit for all upgrade projects. A vertical line may be drawn through the budget limit, intersecting the cost-benefit curve; this intersection then is a cut off point for competing projects.

The relative effectiveness of eliminating or mitigating the risk, based on the proposed cost, can be compared to other proposed projects. This will assist management in allocating resources to the projects presenting the highest risks, after assuring cost effectiveness has been considered.

The Microcomputer Output

The following tables and Figure 1 illustrate typical computer output. The spread sheet format and equations used to derive "Risk Score", "Justification", and "Benefit" are shown in Figure 2. This computer application was developed in 1984 by the LLNL Nuclear Safeguards staff for use by the DOE Office of Military Applications. LLNL began using the microcomputer this year to rank its safety upgrade projects.

Conclusions

LLNL's risk assessment methodology is a refinement of a necessary risk management function, that is to rank order safety upgrade projects in a logical way. With perennially limited funds, a rationale for this ranking is important. We feel our modified NOL risk assessment method can be used satisfactorily by most companies. There are, however, some limitations to this system of assessment. First, the scores derived should only be used for relative positioning of projects. There is no intrinsic value in the numbers derived by the process. The system is ultimately a qualitative methodology. (Scores within 10 or 20 percent of each other can be considered essentially indicating similar importance. This is, of course, due to the subjectivity involved in group assignment of consequence, probability, and degree of correction values.)

A second limitation is consistency of scores between groups of evaluators charged with ranking projects. For example, Group A will not score consequences and probability factors in the same way as Group B. This is due to the unique biases of each group. Similarly, it is unreasonable to expect the same group to be completely consistent in scoring the same projects over a period of time.

With these limitations, the risk assessment method described is superior to purely intuitive methods commonly practiced today. The added dimension of using a microcomputer and spread sheet give the safety staff an additional tool to effectively communicate cost-benefit analysis to management.

Table 4

HAZARD DATA

Facility	Hazard	Risk Score	Consequences	Exposure	Likelihood
A3	Toxic Waste Storage	900	15	10	6
B5	Oxygen Def. Alarms	900	50	3	6
C2	Pigeons	30	1	10	3
A1	HEPA Filters	450	50	3	3
B1	Catwalk	135	15	3	3
B2	Thirty Ton Crane	300	50	3	2
B3	Remote Air Monitors	135	15	3	3
C1	Parking Lot	500	5	10	10
B4	Hand & Foot Counter	90	5	6	3
A2	Roadway	45	5	3	3

Table 5

COST-BENEFIT COMPUTATION

Facility	Hazard	Risk Score	Just.	Cost (1000s)	Cumul. Cost (1000s)	Benefit	Cumul. Benefit
A3	Toxic Waste Storage	900	75.0	6	6	450.0	450.0
B5	Oxygen Def. Alarms	900	15.8	19	25	300.0	750.0
C2	Pigeons	30	10.0	3	28	30.0	780.0
A1	HEPA Filters	450	4.5	50	78	225.0	1005.0
B1	Catwalk	135	3.2	14	92	45.0	1050.0
B2	Thirty Ton Crane	300	3.2	47	139	150.0	1200.0
B3	Remote Air Monitors	135	2.6	17	156	45.0	1245.0
C1	Parking Lot	500	1.7	100	256	166.7	1411.7
B4	Hand & Foot Counter	90	0.9	26	282	22.5	1434.2
A2	Roadway	45	0.3	65	347	22.5	1456.7

Figure 1

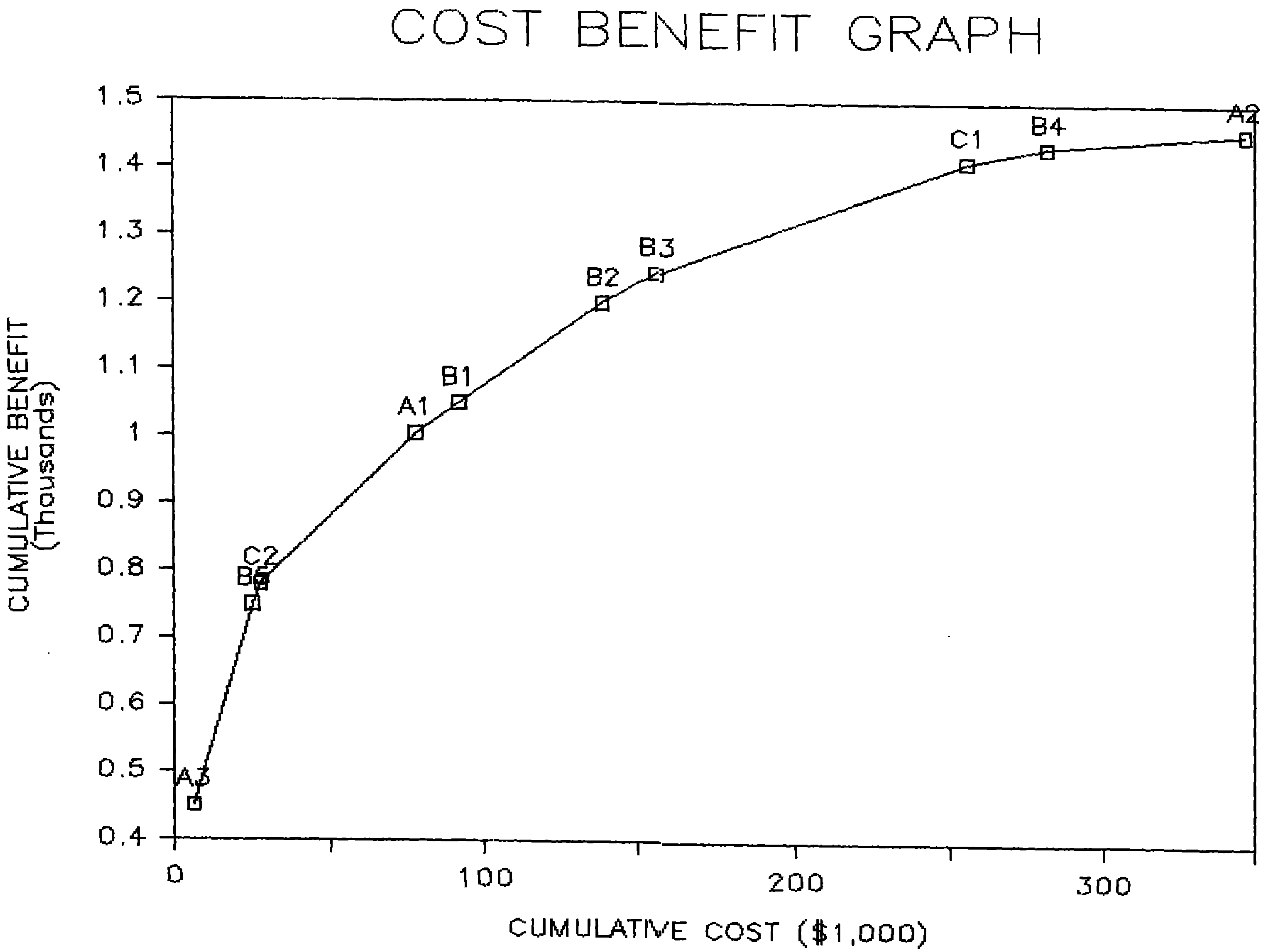
COST BENEFIT GRAPH
CUMULATIVE BENEFIT (Thousands)
CUMULATIVE COST ($1,000)
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
100
200
300
A3
C2
A1
B1
B2
B3
C1
B4
A2

Figure 2

TYPICAL SPREAD SHEET FORMAT

Fac	Hazard	Risk Score	Conse- quence	Expo- sure	Like- lihood	Corrective Action	Deg. of Correct.	Just.	Cost (1000s)	Cumul. Cost (1000s)	Benefit	Cumul. Benefit
A3	Toxic Waste Storage	900	15	10	6	Upgrade Storage Area	2	75.0	6	6	450.0	450.0
B5	Oxygen Deficiency Alarms	900	50	3	6	Install Two Sensors	3	15.8	19	25	300.0	750.0
C2	Pigeons	30	1	10	3	Remove Pigeons	1	10.0	3	28	30.0	780.0
A1	HEPA Filters	450	50	3	3	Upgrade Sys.	2	4.5	50	78	225.0	1005.0
B1	Catwalk	135	15	3	3	Repair Catwalk	3	3.2	14	92	45.0	1050.0
B2	Thirty Ton Crane	300	50	3	2	Certify Crane	2	3.2	47	139	150.0	1200.0
B3	Remote Air Monitors	135	15	3	3	Install Two Monitors	3	2.6	17	156	45.0	1245.0
C1	Parking Lot	500	5	10	10	Resurface Parking Lot	3	1.7	100	256	166.7	1411.7
B4	Hand and Foot Counter	90	5	6	3	Install One Counter	4	0.9	26	282	22.5	1434.2
A2	Roadway	45	5	3	3	Construct Roadway	2	0.3	65	347	22.5	1456.7

Risk Score = Consequences X Exposure X Likelihood Factor

$$\text{Justification} = \frac{\text{Risk Score}}{\text{Cost X Degree of Correction}}$$

$$\text{Benefit} = \frac{\text{Risk Score}}{\text{Degree of Correction}}$$

Reference

1. William T. Fine, "Mathematical Evaluations for Controlling Hazards," Naval Ordnance Laboratory Report No. NOLTR-71-3, March 8, 1971.

Biographies

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